

# GRAVES

Interpoles to Overcome

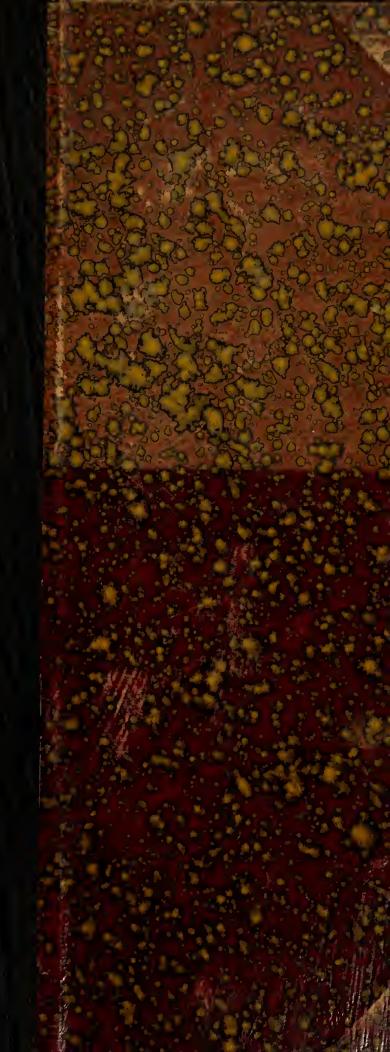
Copper Plating of Brushes

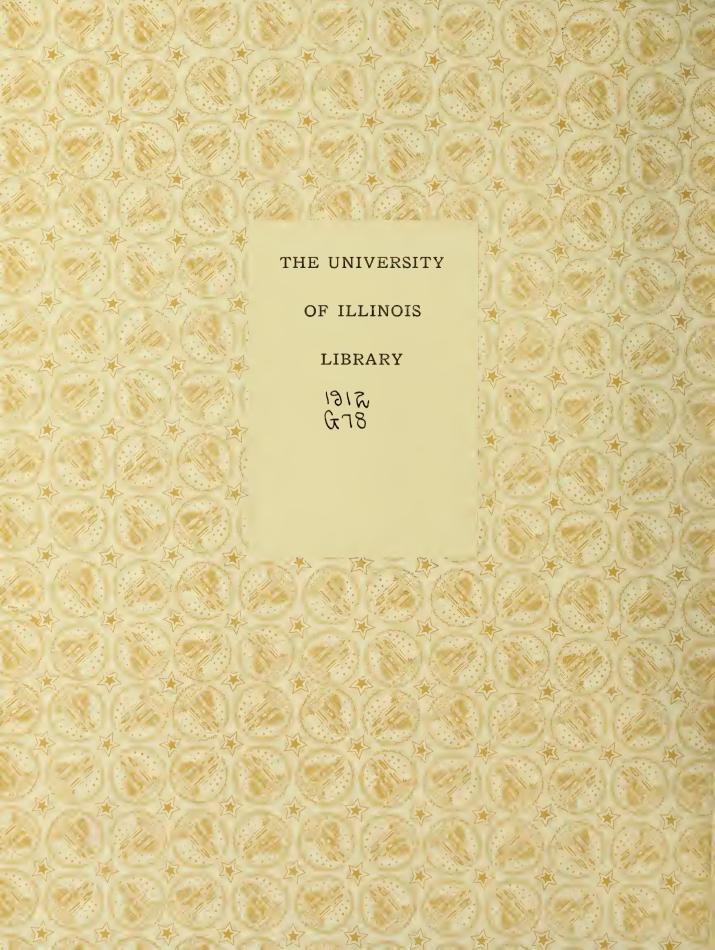
on Direct Current Machines

Electrical Engineering

B. S.

1912







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# INTERPOLES TO OVERCOME COPPER PLATING OF BRUSHES ON DIRECT CURRENT MACHINES

BY

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# THESIS

FOR THE

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IN

ELECTRICAL ENGINEERING

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THIS IS TO CERTIFY THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

LESTER HERBERT GRAVES

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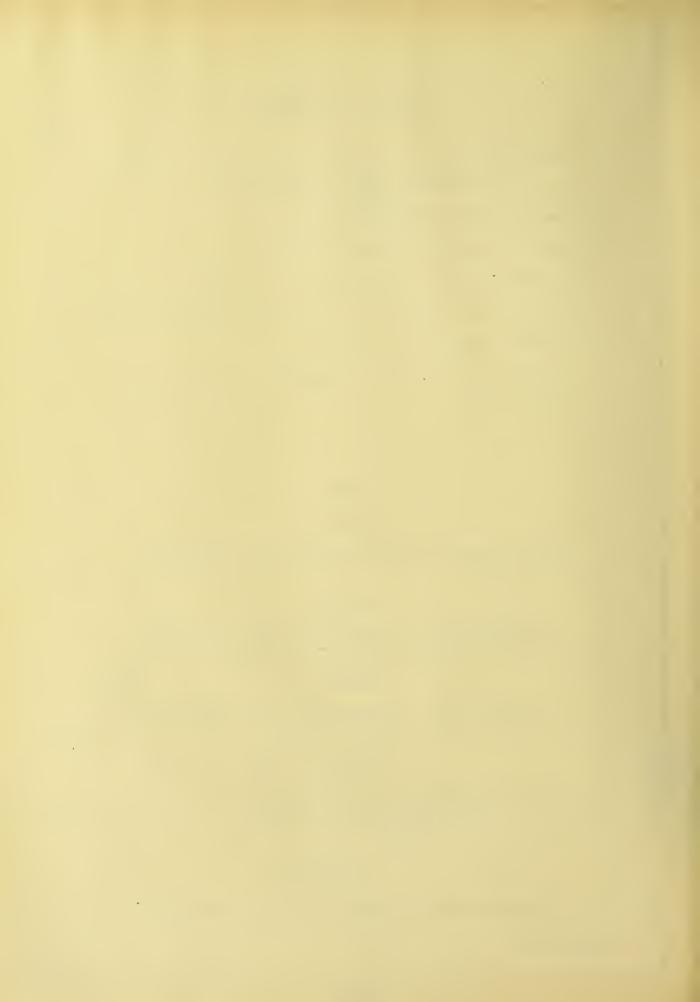
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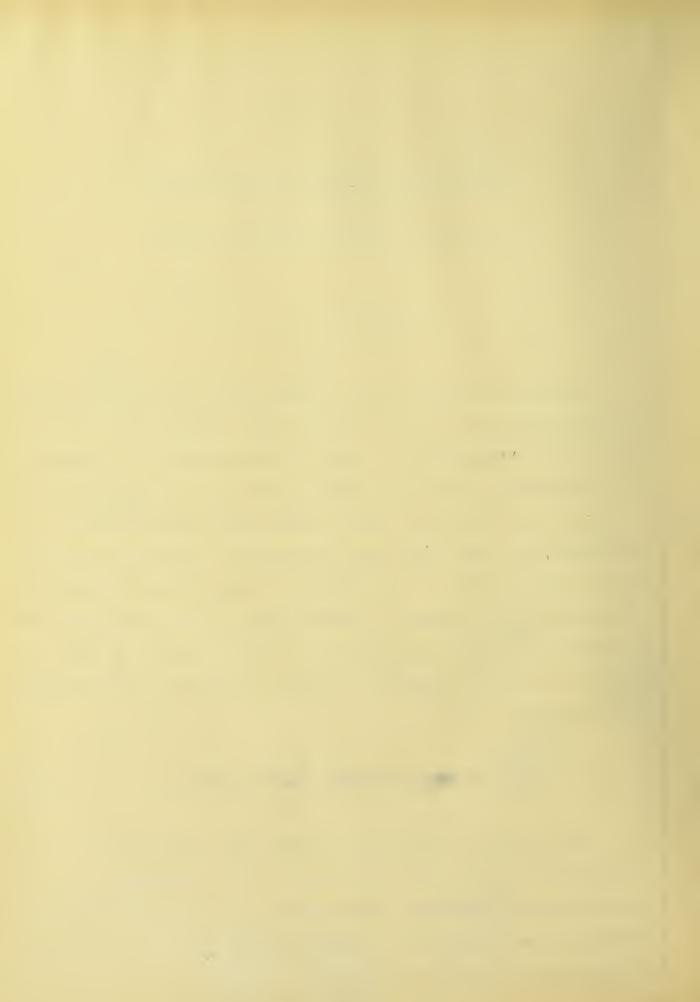
INTERPOLES TO OVERCOME COPPER PLATING
OF BRUSHES ON DIRECT CURRENT MACHINES.

#### I. INTRODUCTION

At present interpoles have entered into the design of direct current machinery to such an extent that in many cases they are now thought indispensable. There are many phases of the question of interpoles and there are many theories as to the real function they have in commutation, but it seems that certain observed phenomena have been cast aside unexplained. An action which has been vividly brought to my attention is the plating or embedding of copper on the brushes of certain direct current generators during the process of commutation. An investigation of this particular phase of commutation led to a study of the application of interpoles.

#### II. AN UNSATISFACTORY PLANT IN CHICAGO.

The presence of this copper plating was first brought to my attention on three 150 K.W. Direct Current Generators in a private plant in Chicago. The machines were pronounced unsatisfactory because commutation without serious sparking and heating



of the brushes was impossible. Upon examination it was found that the brushes were streaked with traces of copper and that all brushes positive and negative seemed to be affected alike. Continued operation caused a greater deposit of copper until sparking occurred even under light loads. Sandpaper was a ready but only temporary remedy. The commutator soon began to show a slightly flaked or pitted surface which immediately gave rise to suspicion that the grade of copper used in construction was poor. Careful tracing thru the factory, however, showed the metal to be of standard quality. To eliminate the possibility of the plating being due to the cutting of the brushes, only slight tension was placed on the brush springs, and also several types of brushes were tried, some of which were exceedingly soft in composition. It was thus shown that the action was not primarily a mechanical one, although considerable heating was noticed, especially after some copper had been deposited on the face of the brushes. Since the springs used were very weak, the heating was evidently due to currents flowing thru the brushes, rather than to mechanical friction. If due to load currents a reduction in load should have affected it, but it appeared that the objectionable plating occured quite as distinctly at no load as at full load, after a run of several hours.

#### III. BRIEF THEORY OF COMMUTATION.

We are thus brought down to a consideration of currents other than load currents which might cause the heating and plating



of the brushes. During the process of commutation one or more coils are short circuited through the commutator by the brush. An e.m.f. is set up in each coil of the armature by the interpolar fluxes present, which tends to send a local current through the coil. Since the magnitude of this local or short circuit current varies with the e.m.f. set up, and since the resistance of the path is exceedingly small, it is possible to realize heavy currents with strong interpolar fluxes acting. To counteract the effect of these fluxes and thus reduce the local currents, interpoles may be introduced.

#### IV. INVESTIGATION OF COPPER PLATING.

Since it is evident that these local currents play an important part in the problem of commutation and especially in the particular phase at hand, i.e., the picking of copper from the commutator, a series of test runs were made on a 11 K.W. Triumph Generator which has been equipped with interpoles since its original construction. The methods used, though somewhat crude, illustrate a feasible means of attack and are sufficiently reliable for the basis of a broad theory in regard to the action mentioned above.

For the purposes at hand the interpoles were disconnected and the machine operated as a shunt generator. The interpoles then served only to lower the reluctance on the interpolar fluxes and thus merely emphasized conditions to be found in the normal machine.



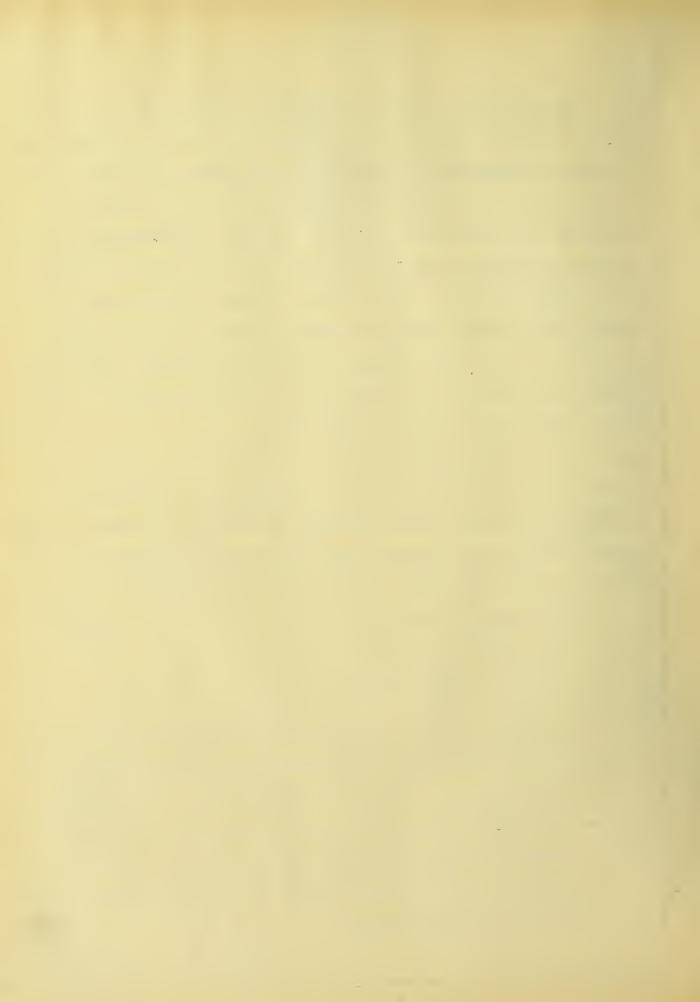
The generator was first operated at rated speed and voltage under a definite load with the brushes in a normal position, and the rise in temperature of the coils and commutator noted for a fixed interval of time. An ordinary 0°-100°C thermometer was used for these determinations. The rise in temperature thus noted was caused by the load currents and local currents flowing in the conductors, and to brush friction and coreloss. A similar run with no load on the machine gave a rise in temperature due to core loss, friction, and local currents. The difference in the heating was plainly due to the load current. Since heat losses are I<sup>2</sup>R losses we may write

Substituting in (1)

$$20^2 = 9.5 \text{ K}.$$

$$K = \frac{400}{9.5} = 42.1$$

By operating with no field excitation, and with the brushes resting on the commutator, the heating due to friction was found. Runs of thirty minutes were used throughout the series, since values thus obtained would lie nearly on the straight line portion of the curve of variation between time and rise in temperature. Standardization rules require a run of from six to fifteen hours to obtain settled temperatures.



The heating due to core loss was determined by operating with the brushes removed. With the friction and coreloss heating values known, the heating due to local currents was readily found.

Now the current in any one coil due to the short circuiting by the brush, flows but a very small portion of the time of one revolution, hence to make current value comparisons by temperature means, an equivalent value of temperature rise must be determined. Assuming, as before, a direct ratio between time and heating for these temperatures, the local current flowing continuously in a coil would give considerable rise.

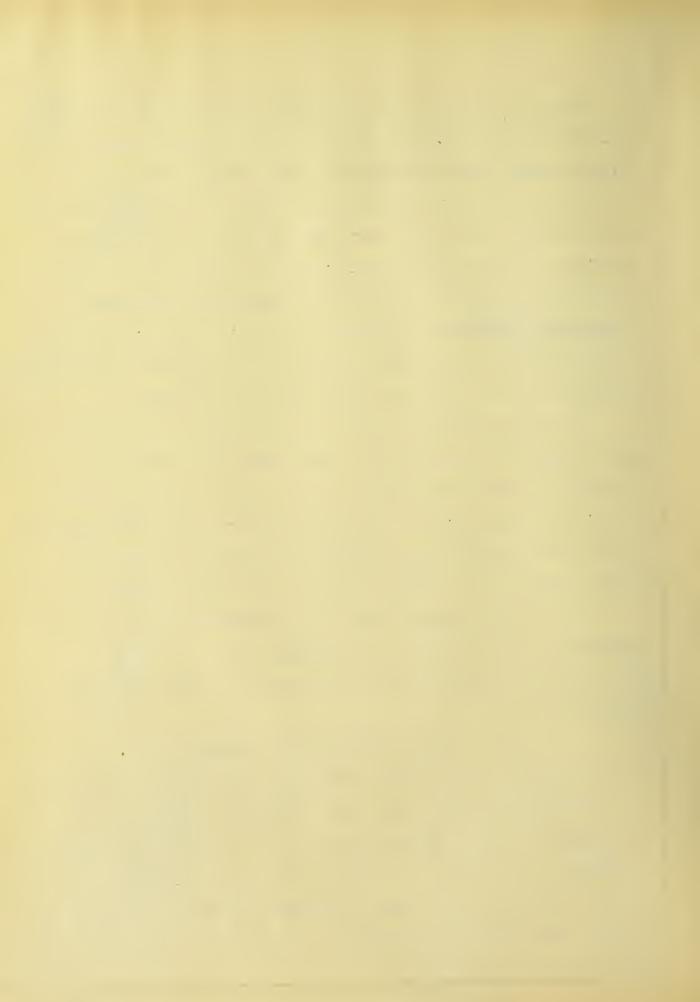
From the commutator data, it is seen that the circumference of the commutator was 25.2 in. The width of a brush was 0.5 in., and since in each revolution a coil was short circuited twice, the actual time of short circuit for any one coil in per cent of a complete revolution was  $\frac{2 \times 0.5}{25.2}$  or 0.0397 of a revolution. This factor may be used to calculate equivalent temperature rises.

Thus if the observed rise on the commutator was 1.1°, the equivalent value to be used is  $\frac{1.1}{0.0397} = 27.7$ .

Using the value of K as determined, the value of local current is

 $I = 42.1 \times 27.7 = 34.2 \text{ amperes.}$ 

The above determinations have been made with the brushes in the normal position. Under these conditions commutation is satisfactory and no copper plating of the brushes is noticed. Shifting the brushes on a direct current machine throws the commutated coil into a region of greater flux density, with a result that the local currents are considerably increased. To

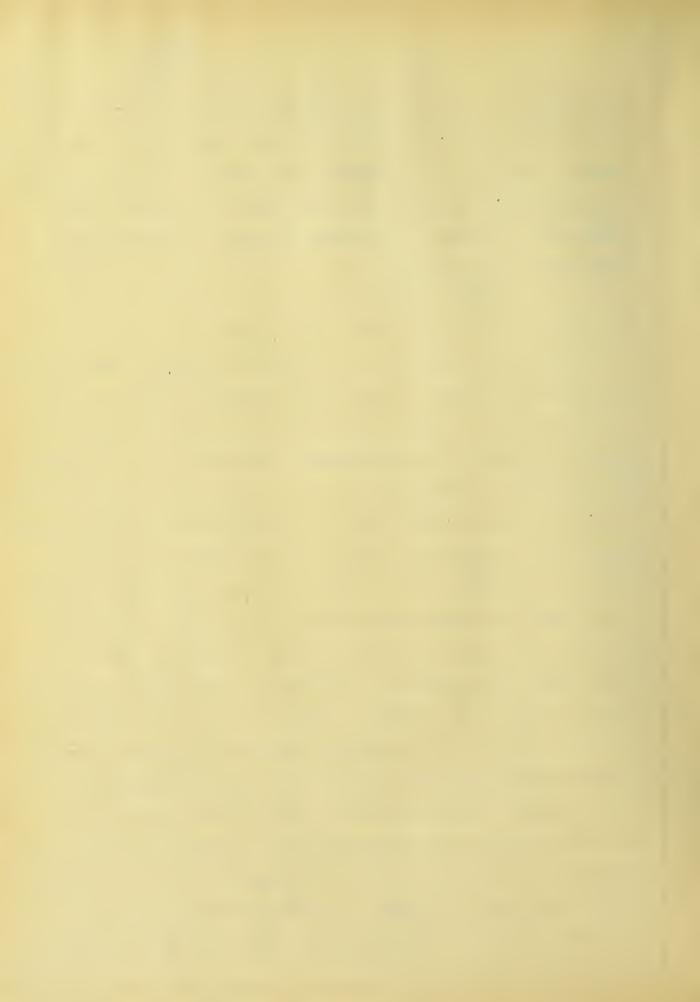


approximate the value of these currents under such conditions, a run similar to those mentioned above was made, with the brushes shifted some six or eight mechanical degrees. The heating data shows that here a rise of 9.3° was found to be due to these currents. As before, the equivalent value of heating may be calculated approximately.

$$0.0397 = 235$$
°C.

From this  $I = 42.1 \times 235 = 100$  amperes.

Under these conditions, the "picking of copper" takes place, and minute particles or flakes may be detected imbedded in the face of the brush. Heavy local currents mean high temperatures, though seemingly only instantaneous. The short circuit is made by the brush, and therefore the latter must conduct these currents. Since the surface of the brush is necessarily more or less pitted, there cannot be perfect contact and there must be an infinite number of small arcs formed under the brush. This arcing action is accompanied by high temperatures as indicated, and although the point of fusion of copper is in the vicinity of 1000 C., the metal loses its properties of hardness to some extent at temperatures as low as 250 to 275 C. Although these temperatures were not quite reached, it is entirely probable that greater instantaneous temperatures were present than could be detected by these methods. Infinitely small flakes of the metal are thus picked up by the brushes passing over the commutator under pressure. Continued operation soon causes a thin film of copper to be coated over the brush. A lower resistance contact is now established, the heating is much increased, and the plating





Α.



B.

Copper Plating of Brush on 11 K.W. Triumph Generator.

- A. Brush after Test.
- B. Brush before Test.



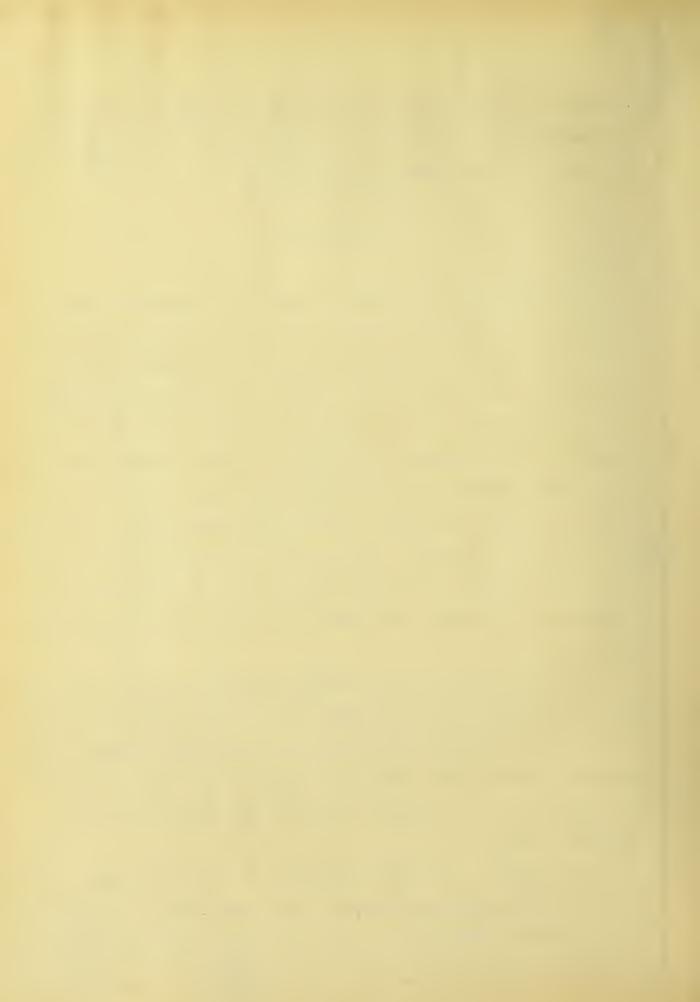
continues. The effects on commutation are evident. Sparking and heating soon become excessive and the effect on the brushes is shown in the accompanying illustration.

#### V. CONCLUSION.

An attempt has been made to show that these heavy local currents are the direct cause of this copper plating of brushes. To eliminate the possibilities of this action taking place on any machine, the objectionable currents must be reduced. The corresponding electro-motive-force is set up by the commutated conductor cutting considerable flux in the zone between the field pole tips. Reducing this interpolar flux then, would in turn reduce the local currents. To accomplish this object, the interpole has been introduced. This interpolar flux, as it has been called, is caused by the magnetomotive force of the armature winding and flows from the armature to the pole tips and yoke of the machine.

Without going into the detailed description of the interpole, it is sufficient here to say that its function in this connection is to set up a counter flux which will opose that existing between the pole tips and thus establish a neutral zone through which the commutated coil may pass without having excessive local currents induced in it.

As a result, interpolar generators do not pick copper. The three machines mentioned early in this paper were all equipped with suitable interpoles to remedy this very trouble and today



they are operating very satisfactorily with almost perfect commutation.

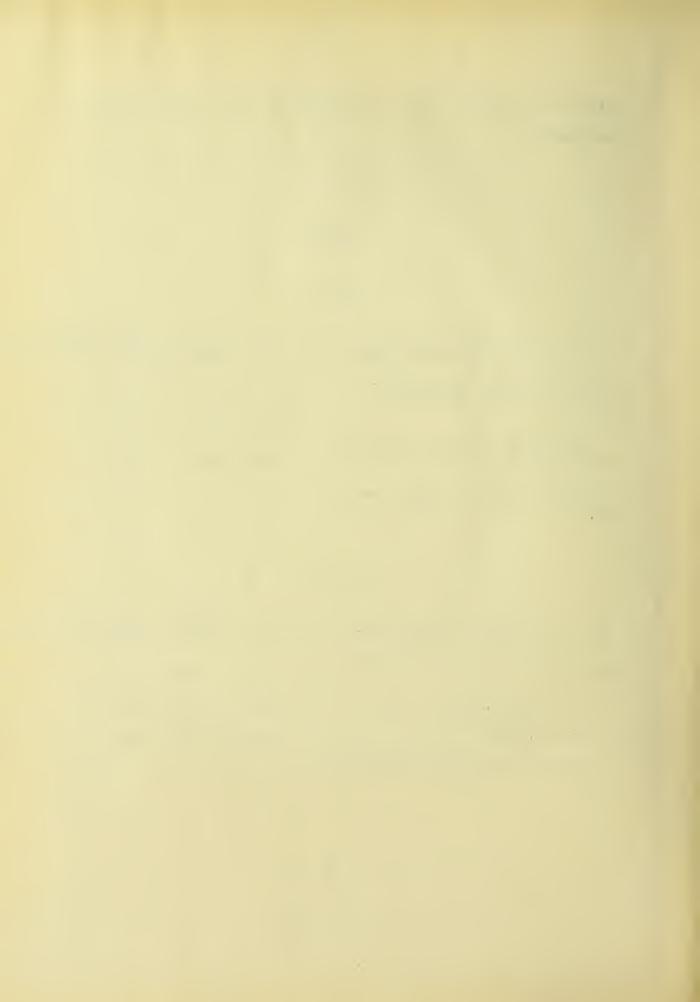
DATA.

TABLE I.

Conditions of Operation.	tı	t <sub>2</sub>		t1-t2 coil.	
Load current, 20 amp.,+ friction + local currents + core loss.	27.0	。 34	55 °	7.0	28.0
Friction + local currents + coreloss.	24.5	° 29 °	43 °	4.5°	18.5°
Rise due to 20 amp. load current.				2.5°	9.5

# TABLE II.

-	Conditions of Operation.	tı	t <sub>2</sub>	t <sub>2</sub>	t <sub>1</sub> -t <sub>2</sub>	t <sub>1</sub> -t <sub>2</sub>
core	Friction + load currents + loss.	24.5	29.0	43.0	4.5	18.5
	Friction alone.	23.8	26.6°	39.6	2.8	15.8°
	Core Loss.	24.2°	25.0°	25.8	0.8	1.6°
	Rise Due to Local Currents.				0.9	1.1°



Conditions of Operation. Brushes Shifted.	tı	t <sub>2</sub>	t <sub>2</sub>	t <sub>1</sub> -t <sub>2</sub> coil	t1-t2
Friction + Local Currents + Coreloss.	27.8°	34.2			
Friction.	23.8°	26.6°	39.6°	2.8°	15.8°
Coreloss.	24.2°	25.0°	25.8°	0.8	1.6°
Rise Bue to Local Currents with brushes shifted.				2.8	9.3°

## COMMUTATOR DATA.

Segme	ents.	٠	•	٠	•	•	•	•	٠	٠	٠	•	٠	٠	•	٠	٠	•	٠	•	69	
Circu	amfere	enc	00	of	C	om	mu	ta	tc	r	•	•	•	•	•	٠	•	•	•	•	25.2	in.
25.2/	/69 =	• 5	365	i	n.	p	θr	S	eg	me	ent											
Width	of H	ru	ısh	l•	•	•	•	•	•	•	•	•	•	٠	•	•	•	•	•	٠	0.5	in.
Coil	short		ir	·cu	it	ed	t	wi	.ce	F	er	· I	·ev	rol	.ut	ii	n,		r			
(2 x	0.5)/	/25	5.2	) ==	0	.0	39	7	of	a	r	ve'	rol	ut	ic	n.						





